Integrated Multitrophic Aquaculture: Filter Feeder Bivalves as Efficient Reducers of Wastes Derived from Coastal Aquaculture Assessed with Stable isotopes

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Introduction

The increase on the demand for fishing products has entailed a major development of the aquaculture activities. Integrated Multitrophic Aquaculture (IMTA) has emerged as a potential tool to mitigate the environmental impacts of the organic enrichment from aquaculture facilities, by integrating fish with low-trophic organisms (molluscs and/or algae) during farming through the recycling of particulate and dissolved compounds (Cheshuk et al., 2003).With the aim to introduce a sustainable aquaculture in the Mediterranean, we developed an IMTA system by culturing bivalves *Mytilus galloprovincialis* (Lamarck, 1819) and *Mimachlamys varia* (Linnaeus, 1758), with fin fish Argyrsomus regius (Asso, 1801) during years 2008-2011, in the Balearic Sea (Deudero *et al.*, 2011).

Materials and methods

The study was conducted at a research experimental station (LIMIA), in Andratx Bay, on the SW coast of Mallorca at 6 floating cages with cultured *A. Regius*, and at two references sites. Control 1 was located 350 m away from the fish cages within Andratx Bay and control 2. 21 nautical miles away. In the experimental site (hereafter called cage site), approximately 10 adult specimens of *A. regius*, and 6 samples of *M. galloprovincialis* and *M. varia* were sampled seasonally. In control sites, 6 specimens of *M. galloprovincialis* and *M. varia* were sampled seasonally. Additionally, in the cage site potential food sources derived from aquaculture wastes (fish faeces, pellet and fresh food) were seasonally sampled and in all sampling sites *Holothuria (panningothuria) forskalii* Delle Chiaje, 1823, phytoplankton, zooplankton, particulate organic matter (POM) and sedimentary organic matter (SOM) were also sampled.

Samples were frozen immediately after collection for posterior isotopic analysis. Carbon and nitrogen isotopes were analyzed following standard procedures (Deudero et al., 2004). Isotope ratios were calculated according to the equation: $\delta^{13}C$ or $\delta^{15}N = [(R_{sample}/R_{reference}) - 1] \times 1000$ where R is the corresponding $^{13}C/^{12}C$ or $^{15}N/^{14}N$ ratio. A distance based permutation analysis of variance (PERMANOVA) was applied to test differences in the isotopic signature of filter feeders between treatments and sampling periods. SISUS Bayesian Mixing model (Stable Isotope Sourcing using Sampling) was applied to quantify the feasible contributions of the potential organic matter sources to the bivalves' diet.

Results

Statistical analyses showed significant differences between cage and control treatments and seasons for ^{13}C and ^{15}N in *M. varia* while *M. galloprovincialis* showed significant differences between treatments, season and year for ^{13}C and between treatments and seasons for ^{15}N ($p<0.05$). *M. galloprovincialis* from cage site showed an enrichment of 0.11‰ in ^{13}C and 1.33‰ in ^{15}N compared to bivalves from control 1; greatest differences were found when comparing with control 2, with an enrichment of 1.44‰ in ^{13}C and 3.07‰ in ^{15}N ($p<0.05$). Mean ^{13}C values of *M. varia* from cage site, were -19.80 ± 0.44 ‰ and 7.47 ± 0.70‰ for ^{15}N, showing an enrichment of 0.32‰ and 1.74‰ in ^{13}C and ^{15}N, respectively, compared to control 2 ($p<0.05$). According to the bayesian mixing model, the main food source for *A. regius* was pellet food, with a mean global contribution of 72.35%. Pellet food represented an important food source for *M. varia*, with a mean contribution of up to 62.68 % (Fig1). Contributions varied both seasonally and annually, however, aquaculture derived products remained the main food sources. Pellet food represented the main food source for *M. galloprovincialis*, with a mean contribution of 57.95% (Fig 2). *M. galloprovincialis* also showed seasonal and annual variation, but again aquaculture derived products remained the main food sources.

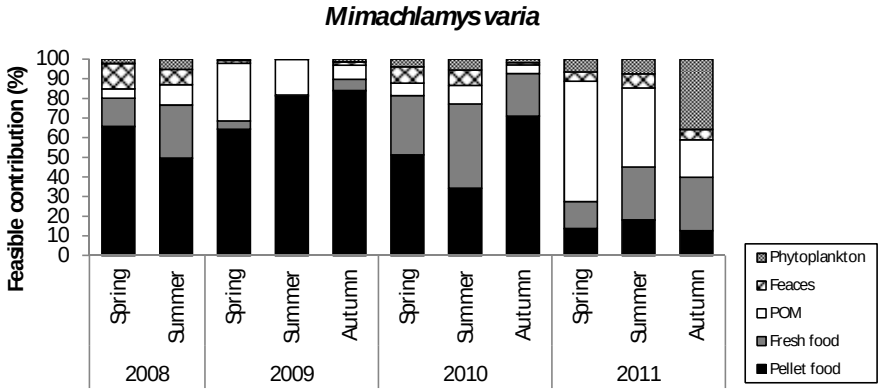

Fig. 1. Seasonal and annual variability of feasible contribution of the main organic matter sources to the diet of Mimachlamys varia cultured in fish cages based on Bayesian mixing models.

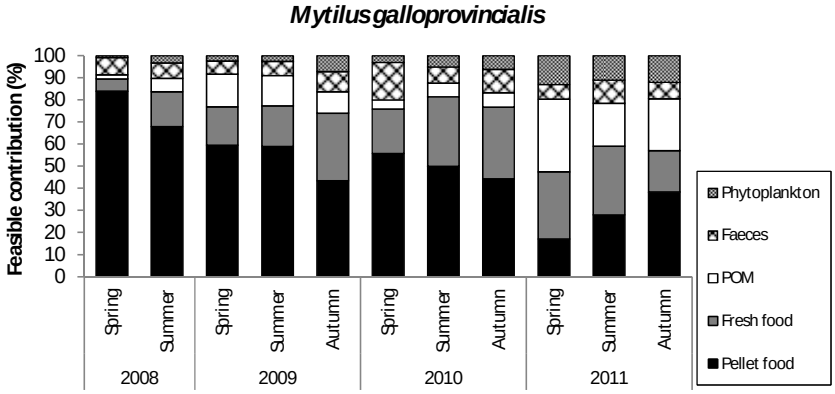

Fig. 2. Seasonal and annual variability of feasible contribution of the main organic matter sources to the diet of Mytilus galloprovincialis cultured in fish cages calculated by Bayesian mixing models.

Discussion

This study demonstrates the potential of bivalves to reduce organic enrichment and reflects the efficiency of IMTA systems in the oligotrophic waters of the Mediterranean. Bivalves from cage sites showed ^{15}N signature relatively similar to those of phytoplankton, zooplankton, fresh food, fish faeces and benthic sedimentivorous, demonstrating that filter feeders worked efficiently by achieving their nitrogen isotopic signature from the filtered substances. The enrichment in ^{15}N shown by *H. forskalii* in cage site is derived by the incorporation of aquaculture wastes that sink into the seaflor as it has been observed previously (Dolenec et al., 2007). Higher $\delta^{13}C$ values for *M. galloprovincialis* and *M. Varia* exhibited in the cage site are probably linked to the higher water residence time in the inner bay, while control sites are at open areas. The annual variability of the feasible contribution of pellet and fresh food to *A. regius*' diet is atttributed to the nutritional regime instead of a change in the intake nutrient strategy. Particularly important are the mixing model analysis in both bivalves, as it strongly demonstrates a contribution of aquaculture wastes in both bivalves' diet. For both bivalves, food contribution seemed to be complementary; when one specie increased the intake of pellet food, the other one exhibited a decrease in that contribution and vice versa. This could be interpreted as a competetive strategy between both species, possibily due to the limitation of water income and nutriets produced by the bags where they are simultaneously placed. The results clearly demonstrate that both bivalves are assimilating aquaculture derived wastes efficiently, supporting the idea that the co-culture of species with different trophic strategies guarantees a good environmental status by improving water quality in fish farms. The incorporation of filter feeders in aquaculture installations is in line with the European water framework directive 2000/60/CE which aims to guarantee and maintain a good state of water bodies.

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